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Title:

METHOD FOR FILLING VIA WITH METAL

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METHOD FOR FILLING VIA WITH METAL

BACKGROUND

[0001] The present invention relates to the field of memory devices. More particularly, the present invention relates to a method for filling vias in memory devices with metal.

[0002] A well known semiconductor memory component is a random access memory (RAM). RAM permits repeated read and write operations on memory elements. Typically, RAM devices are volatile, in that stored data is lost once the power source is disconnected or removed. Non-limiting examples of RAM devices include dynamic random access memory (DRAM), synchronized dynamic random access memory (SDRAM) and static random access memory (SRAM). DRAMs and SDRAMs typically store data in capacitors which require periodic refreshing to maintain the stored data. The periodic refreshing process drains power, thus lowering the amount of time computing devices such as lap top computers can be used apart from a constant power source.

[0003] Recently resistance variable memory elements, which include programmable conductor random access memory (PCRAM) elements, have been investigated for suitability as semi-volatile and non-volatile random access memory elements. Generally a PCRAM element includes an insulating dielectric material formed of a chalcogenide glass disposed between two electrodes. A conductive material, such as silver, is incorporated into the dielectric material. The resistance of the dielectric material can be changed between high resistance and low resistance states. The programmable

conductor memory is typically in a high resistance state when at rest. A write operation to a low resistance state is performed by applying a voltage potential across the two electrodes.

[0004] When set in a low resistance state, the state of the memory element will remain intact for minutes or longer after the voltage potentials are removed. Such material can be returned to its high resistance state by applying a reverse voltage potential between the electrodes from that used to write the element to the low resistance state. Again, the highly resistive state is maintained once the voltage potential is removed. This way, such a device can function, for example, as a resistance variable memory element having two resistance states, which can define two logic states.

[0005] With specific reference to FIGS. 1A-1C, one method of forming a conventional PCRAM cell is shown. A first conductor 12 is formed on a substrate 10. Then, an insulator 14 is formed on the first conductor 12, and a via 18 is formed in the insulator 14. Then, a metallic material 16 such as silver is deposited on the insulator 14 and in the via 18, after which a polishing step removes the metallic material 16 from the surface of the insulator 14. Then, a chalcogenide glass 22 is deposited over the metallic material 16, followed by a metal-containing layer 24 and a second conductor 26. Then, a second polishing step removes the chalcogenide glass 22, metal-containing layer 24 and second conductor 26 everywhere but within the via 18.

[0006] One undesirable aspect which has been observed with the above-described method is that the first polishing step sometimes pulls the metallic material 16 out of the via 18 leaving no metal in the via 18 as shown in FIG. 1B. In addition, an

undesired build up of slurry residual in the via 18 from the first polishing step has also been observed.

SUMMARY

[0007] The invention provides a method for forming a metal layer in a via that includes forming a metallic material on a surface of an insulator and within and over a bottom of the via, forming a hard mask over the metallic material in the via, removing the metallic material from the surface of the insulator, and removing the hard mask from the via.

[0008] The invention also provides a method for making a programmable conductor random access memory. The method includes forming a first conductor on the substrate, forming an insulator on the substrate, forming a via in the insulator extending to the first conductor, forming a metallic material on a surface of the insulator and in the via in contact with the first conductor, forming a hard mask over said metallic material within the via, removing the metallic material from the surface of the insulator, removing the hard mask, forming a chalcogenide material in the via in contact with the metallic material, forming a metal-containing material in the via in contact with the chalcogenide material, and forming a second conductor on the surface of the insulator and in contact with the metal-containing material.

[0009] The invention also provides a programmable conductor random access intermediate structure that includes a substrate, a first conductor formed on said substrate, an insulator formed on said first conductor, at least one via formed within said

insulator and extending to said first conductor, a metallic material formed in said at least one via, and a hard mask formed on said metallic material within said at least one via.

[0010] These and other advantages and features of the invention will be more readily understood from the following detailed description of the invention which is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1A is a schematic view of a PCRAM cell being formed in accordance with a conventional process.

[0012] FIG. 1B is a view of the PCRAM cell of FIG. 1A with the metallic material removed from the via.

[0013] FIG. 1C is a schematic view of the completed PCRAM cell of FIG. 1A.

[0014] FIGS. 2A-2D are schematic views of the formation of a PCRAM cell in accordance with an embodiment of the invention.

[0015] FIG. 3 illustrates a method for forming a PCRAM cell in accordance with an embodiment of the invention.

[0016] FIG. 4 is a schematic view of a PCRAM cell formed by a method in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0017] Referring now to FIGS. 2A-4, the invention will now be described with reference to the formation of a programmable conductor random access memory (PCRAM) cell. It should be understood that the utilization of a PCRAM cell is illustrative in nature only and in no way is meant as confining the utility of the invention to formation of a PCRAM cell.

[0018] In forming a PCRAM cell, such as PCRAM cell 300 (FIG. 4), a PCRAM intermediate structure 100 is formed by, for example, depositing a first conductor 112 on a substrate 110. The first conductor 112 may be formed of any suitable conducting material, such as, for example, tungsten, nickel, tantalum, titanium, titanium nitride, aluminum, platinum, and silver, among many others. The substrate 110 can be formed of any suitable material, such as, for example, semiconductor materials or insulating materials such as silicon or plastic. An insulator 114 is then formed on the first conductor 112 by, for example, deposition. The insulator 114 may be formed of any suitable insulating material, such as silicon nitride. A via 118 is then formed in the insulator 114 through any suitable process, such as, for example, patterning a masking material on a surface 115 of the insulator 114 and etching to remove unmasked portions of the insulator 114.

[0019] After the via 118 is formed, and the masking material has been removed from the surface 115, a conductive material, such as a metallic film 116, is formed on the surface 115 of the insulator 114 and within the via 118 at step 200 (FIG. 3).

Preferably, the metallic film 116 is formed through a deposition process, and most preferably through a plasma vapor sputter deposition of the metallic material. As illustrated, the metallic film 116 resides in a portion of the via 118 in contact with the first conductor 112 and does not adhere to the sides of the via 118. The lack of adherence of the metallic film 116 on the sides of the via 118 is due to poor step coverage of the plasma vapor deposited metal. Preferably, the metallic film 116 is a film of silver which is formed through a plasma vapor sputter deposition of silver.

[0020] After deposition of the silver film 116, a flowable oxide 120 is deposited in the via 118 over the silver film 116. The flowable oxide 120 has high mobility and it behaves like a liquid on a surface. Thus, the presence of the via 118 on the surface 115 of the insulator 114 allows the flowable oxide 120 to flow into the via 118 before distributing on the surface 115 (FIG. 3). Preferably, the flowable oxide 120 is deposited through a chemical vapor deposition using trimethylsilane and ozone as precursors. Through this process, the highly mobile flowable oxide 120 flows to fill the portion of the via 118 directly above the silver film 116, does not adhere to the sides of the via 118, and does not remain lodged at the open end of the via 118. The flowable oxide 120 is preferably silicon oxide, or alternatively, may be formed of a spin-on material having high mobility and being suitable to protect the metallic film 116.

[0021] The flow step 210 is performed at a relatively low temperature, specifically in the range of about 50 °C to about 90 °C. A low temperature process is advantageous because a phase transition may occur at higher temperatures and silver from

the silver film 116 may diffuse into surrounding material in the PCRAM intermediate structure at higher temperatures. Even at such low temperatures, the surface tension of the flowable oxide 120 is sufficient to drive the flowable oxide 120 to cover the silver film 116. The flowable oxide 120 forms a hard mask that serves to protect the silver film 116 positioned beneath the flowable oxide 120.

[0022] Next, at step 220 (FIG. 3), the silver film 116 is removed from the surface 115 of the insulator 114 by a suitable process, such as, for example, dry sputter etching. By dry sputter etching, the silver film 116 may be completely removed from the surface 115. A portion of the flowable oxide 120 within the via 118 may also be removed through the dry sputter etching. At 500 eV, a 1 mA/cm² sputter of argon corresponds to a sputter rate of 1833 Å/s for the silver film 116 and only 400 Å/s for the flowable oxide 120. Thus, the flowable oxide 120 serves as a sufficient barrier against the deleterious effects of the dry sputter etching on the silver film 116 covered by the flowable oxide 120 within the via 118.

[0023] Finally, at step 230 (FIG. 3), the remaining oxide material 120 is selectively removed. A suitable removal process is used, such as, for example, providing a hydrogen fluoride solution that etches silicon oxide (flowable oxide 120) at a much faster rate than either silicon nitride (insulator 114) or metal (metallic film 116). Through the foregoing process steps, a via 118 is formed with a metallic film 116 contacting a conductor 112 within the via 118.

[0024] With specific reference to FIG. 4, next a glass material 122 is recessed in the via 118 through either a dry or wet etch. One exemplary wet etch incorporates NH_4OH , while one exemplary dry etch incorporates a fluorine based chemistry, though any dry etch capable of removing oxides would be suitable. The glass material 122 may be a chalcogenide glass. One preferred chalcogenide glass is germanium-selenide glass with a $\text{Ge}_x\text{Se}_{100-x}$ stoichiometry between about $\text{Ge}_{20}\text{Se}_{80}$ to about $\text{Ge}_{43}\text{Se}_{57}$.

[0025] Then, a metal-containing material layer 124 is formed in the via 118 over the glass material 122. The metal-containing material layer 124 is then planarized to remove any of the layer from the surface 115 of the insulator. The metal-containing material 124 is preferably silver-selenide. Finally, a second conductor 126 is formed over the surface 115 of the insulator 114 and over the metal-containing layer 124.

[0026] What is claimed as new and desired to be protected by Letters Patent of the United States is: